Rover Races

Goal: The students will learn the challenges of operating a planetary rover and problem solve solutions by using a hands-on simulation.

Objective: To have the rover driver design and execute a series of commands that will guide a human rover through a simulated Martian surface, allowing the rover team to experience some of the challenges of teleoperating a robotic vehicle on another planet.

Time Frame: 45 minutes

National Science Education Standards:
Standard G: Nature of science

National Math Education Standards:
NM.5-8.2 Communication
NM.5-8.13 Measurement

National Technology Education Standards:
NT.K-12.3 Technology Productivity Tools
NT.K-12.4 Technology Communication Tools

Items Needed:

- Large playing area (classroom, gym, or outside area)
- Three blindfolds per team
- A clipboard and pencil for each driver and official
- Obstacles - laminated construction paper works well (**note:** do not use any materials that the blindfolded students will trip or fall over).
- A stopwatch for the timer of each team
- Driver's sheet
- Job cards with team numbers

Background Information:

Many students think that robotic vehicles (like the Mars Pathfinder Sojourner Truth rover) can be driven much like they drive their toy radio-controlled cars. They imagine a rover driver watching a computer screen showing the rover on Mars and moving a joystick to make it go. The reality is not so! The time it takes for a command to reach the surface of another planet (such as Mars) varies with the distance between the planets involved. This prevents any "joy-stick" driving in real time. The commands travel via radio waves at the speed of light (186,000 miles / second) and can take many minutes to reach their destination. Much can happen to an interplanetary robotic vehicle during this time interval. If, for instance, a command were given from the Earth-base for it to go forward on Mars and the Earth-base got a reply (say 12 minutes later) saying that the rover was indeed traveling forward. It would then take another 12 minutes to send a command from the earth-base to stop the rover. If the rover runs into trouble, crashes, or flips over, there is no one there to fix the situation. The rover mission is over!

In real remote sensing operations using robotic vehicles, NASA uses "smart rovers." Rovers are programmed with artificial intelligence that helps to keep it out of trouble. During the Mars Pathfinder mission, the mission science team would decide, as a group, which areas of the landing site or which particular rocks located in the landing site they wished to investigate. This information was relayed to the rover driver. The driver, viewing the landing site on a computer screen and using *Virtual Reality* goggles, then designed and uploaded the commands to the rover on which target it needed to find. The rover would then "think" its way over to that target…very slowly (another big difference between the toy cars that often speed around and crash!)

The *Sojourner Truth* rover (JPL website: http://marsweb.jpl.nasa.gov) was equipped with a camera and lasers that sent a series of beams out in front of the rover. If the beams came back unbent, it meant that the way was clear of obstacles. The rover would then move 1/2 a wheel turn and stop. It repeated this cycle, slowly moving toward the designated target. If the beams come back bent, the rover decided how bent (how big of a rock or crater is in front of it) and chose to either go over the obstacle, if it was small enough, or avoid it all together by going around it. Eventually, the rover arrived at the predetermined target, ready to collect the science data. Once the rover reached the target, it used its camera to take a closer look or deploy a special instrument called the APXS (Alpha-Proton X-ray Spectrometer) to analyze the rock. The Sojourner rover was not designed to travel very far away from the lander (approximately 15 meters). The lander camera kept the rover in view at all times.

The *Athena* rover payload (Athena website at http://athena.cornell.edu), was designed for the Mars Explorer Rover Mission due to launch in 2003. These rovers are even smarter and bigger rovers! This "super-rover" will be much like a roving geologist on Mars. This rover will have a lot more instruments available onboard to test rock samples, soil samples, and conduct science experiments. This rover will travel much farther away from the lander (up to 1 kilometer) and have its own navigation capabilities. The Mars Explorer Rover will have a series of cameras (navcam, pancam, hazcam, and a bellycam) and will be able to send back different camera views for the scientists on Earth to see. As each rover travels across the surface of Mars, the scientists will periodically stop, have the panoramic camera take a picture, then pick an area in the camera's view to. Send the rover. Rocks will be selected for imaging up close by the camera and the microscopic imager. Since a reddish dust covers much of the rocks and surface of Mars, a special instrument called the Mini-Thermal Emission Spectrometer (mini-TES) will use an thermal infrared (TIR) detector to look through the dust and view what type of rock or mineral might be near the rover. Other types of instruments on the rover will be able to take other important scientific readings about the rocks they encounter.

Before any robotic vehicle (such as a rover) is sent into space to journey to another planet, it is tested here on Earth first. Scientists are already testing the prototype of the Athena rover. This prototype is called the FIDO (*Field Integrated Design and Operations*) rover and was tested the spring of 1999 and 2001 (FIDO website at http://fido.jpl.nasa.gov and http://wufs.wustl.edu/lapis2) in the western U.S. deserts by scientists and high school students.

<u>Preparation</u>:

1. Prepare a set of job cards for each rover team. Use 3” x 5” index cards, making a driver card, 3 rover cards, a timer card, and a judge card for each team.
2. This makes it easier to assign the next group of students by handing out the cards to reserve their role.
3. Use construction paper ties (red 12” x 12” work well) to create the obstacle course that the rovers will traverse. Laminated ties work the best and last for many uses. Do not use desks or chairs, as students may trip over them. Make any type of course by arranging the ties symmetrically. An easy example of this might be:

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     0      0      0      0
     0      0      0      0                 0 = rover teams
     0      0      0      0
      STARTING LINE
X      X      X      X      X
XX     XX     XX     XX   XX
X      X      X      X      X
X    X    X     X     X    X
X  XX    XX    XX    XX    X
X    X    X     X     X    X
XX  XX   XX  XX    XX  XX
X  X   X    X    X    X   X
        FINISH LINE
```

<u>Procedure</u>:

1. Preface the activity with a lesson on planetary rovers (e.g. Sojourner, FIDO, or Athena). Good resources can be found at the APEX/Athena website at http://athena.cornell.edu or the Jet Propulsion Laboratory website at http://marsweb.jpl.nasa.gov or the FIDO website: http://fido.jpl.nasa.gov and http://wufs.wustl.edu/lapis2)
2. Choose or draw names of students to form teams of six. One student will be designated as "the rover driver", one will be the "team timer", and another will be the "team judge". The remaining three students will become the rover by hooking together in a line (both hands to the shoulders in front of them (O=O=O). The rover will be guided by the driver through an obstacle course (simulated Martian surface).
3. The drivers will proceed through the course first, writing down the instructions that will guide the rover through the course (i.e. 3 steps forward, stop, 1 step left, stop, etc.)
4. Once the drivers have recorded their upload sequences on their driver sheets, the rover races can begin. The rover teams line up at the starling line. The three rover members are blindfolded, as to not aid the driver in executing their commands. The rover members link up (to form the 3 sets of wheels like the real rover designs) with their hands on the shoulders of the person in front of them (it is fun to choose different-sized students to form a rover, as the different sizes of steps taken by each is more evident). The judges

will keep a tally of the number of foot faults that their rover team makes by counting each time the front rover person's foot steps on a red tile (Mars rock). The timer of each team will record the time it takes for their rover team to make it through the course. (NOTE: remind the teams that accuracy, not speed is more important when driving a robotic vehicle on another planetary surface.)

5. The teams will all start at the same time, with the timers starting the team stopwatches when the teacher indicates. The driver may stand near their team to give the command sequences, but may not physically touch their rover to help guide it (this is, after all, teleoperations!). They must guide their rover by voice only. The rover driver may not deviate from the commands that have been written in their previous trip through the course, even if the rover is going off course. Many times in robotic missions, a sequence of commands are sent all at once. Changes have to be added later.
6. Allow time for all teams to complete the course. Gather the class to debrief how the driving went - the challenges and what they might change to do a better job the next time.
7. The students might observe that their steps and those of the rover people might need some type of calibration (i.e. “take baby steps” or “take giant steps”). Turns might be more accurate by saying, “turn 45 or 90 degrees”. Running a rover with 3 axles is also different than walking a course singularly.
8. Repeat the activity as time permits, allowing the changes the students brainstormed to be tested

Race Variations:

1. Safety cones can be added to the course as return sample rocks to be collected. When the rover is in the proper position for the last person on in the rover team to bend down (blindfolded) and pick up the cone, the driver can command “retrieve rock sample”. Once the cone has been retrieved, the cone can be passed to the middle rover person to be carried.
2. A video camera and monitor could be set up, so that the driver is in another room, allowing for a closer simulation to teleoperation. The driver would have to interpret the images and driving pathway with only the camera images (camera being held by the lead rover person) to guide them. Commands could be sent via a “runner” student, simulating the wait time that occurs in real space communication. Real communication with Mars varies with the distance between Earth and Mars (4 minutes to 20+ minutes each way.)
3. The tiles can be arranged in any design to make the course easier or more difficult (according to grade level or student's ability.) If course is set up outside you might want to tape the underside of the tiles, to prevent the course being disturbed by any wind.
4. Talk about the time differences the teams took to complete the course. Are there advantages to taking it slower (more careful moves, less crashes) or perhaps the power supply is getting low and more territory needs to be covered (faster).

Extensions:

1) Have students design or build their own rovers, explaining what type of Instrumentation they would include and why it is necessary.

2) Have students research the types of rovers or other types of robotic spacecraft that are already traveling toward their destination or are being developed for solar system exploration. Another examples is:

   The MUSES C Mission (asteroids) website:

   http://sse.jpl.nasa.gov/missions/ast_missns/muses.html

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Rover Races

Information Sheet and Course Directions for Driver

<u>Commands</u>:

Right	(R)
Left	(L)
Backward	(B)
Forward	(F)
Stop	(S)
Rock Sample Retrieval	(RSR)

1) Write down the course directions for the rover to follow, counting your steps as you walk through the Mars course.

2) When the rover is in the correct position for the last person of the rover to collect a rock sample, use the Rock Sample Retrieval command.

3) The rover will only be able to follow your set of written commands. The commands to the rover cannot be any different than the ones you have written down.

<u>Commands</u>: (Example - 1. Forward 3 steps. Stop.
2. Turn left 1 step. Stop.)

1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

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Judges Sheet

Make a mark (example: IIII) every time the first person on the rover team steps on a tile (rock crashes!). Keep track through the whole course and make a total at the end.

NAME OF JUDGE:

NAME OF TIMER:

TOTAL ROCK CRASHES =

TOTAL TIME TO COMPLETE THE COURSE =

TOTAL ROCK SAMPLES COLLECTED